Climate Change: it’s not just our kids’ problem anymore

Recent headlines convey a sense of climate urgency, which is likely warranted as this decade may be the last chance to act. Climate change is not just an “E” problem in ESG: the social costs are high, with forecasts of 1.8bn people set to live in absolute water scarcity by 2025, 100mn pushed into poverty, and 800mn at risk from rising sea levels. And climate migration could reach 143mn from LatAm, Sub Sahara and South East Asia driven by extreme weather. The potential impact on the economy and markets could be significant: economic damage could equate to >3% of GDP loss every year by 2030, growing to US$69tn by 2100; c.5% of global equity stock market value (US$2.3tn) could be permanently wiped out by climate policy re-pricing, and the potential impact to corporate earnings could be extreme for certain sectors. When environmental, economic and social megatrends collide, it often impacts political, geopolitical and globalism paradigms. The good news: we have economically viable, socially demanded and technologically proven solutions that could create a >US$2tn pa investment opportunity by 2025.

The other side of the debate

Accounting for 40%+ of direct and indirect global emissions, the Energy sector has been a frequent target of divestments – and has shrunk from 16% of the S&P 500 in mid-2008 (peak) to c. 5% today. With US$20tn poised to be invested in ESG-focused funds over the next few decades (roughly the size of the S&P 500 today) capital allocation to Energy could be further choked off. Our Oil & Gas analysts warn that inadequate capital investment in the sector to sufficiently support a seamless transition to a low-carbon economy, which will take decades to complete, is a key risk.

“How many degrees can your portfolio withstand?”

Our clients are increasingly being asked about climate risk by asset owners, and climate change is the #1 cited ESG risk. Assessing investment risk relies on good disclosure, which is improving, but is far from comprehensive. US companies that disclose Scope 1/2 emissions currently trade at almost a full turn of premium on book value to those that do not disclose. Economic impact could be meaningful, for example higher carbon prices of US$100 per ton of CO2 could reduce S&P 500 earnings by up to 13%.

Threat becomes opportunity: >$2tn market in the 2020s

However we believe the 2020s are shaping up to be the decade of climate opportunity. The climate solutions market could almost double from c.US$1tn pa now to >US$2tn pa by 2025 (>9% pa CAGR). Renewables (cheaper than fossil production), electric vehicles (30% of all new cars sold by the end of the decade), batteries, biofuels, efficiency and the circular economy are winners longer-term. Finally, moonshots such as geo-engineering, the scale-up of climate-controlled farming, carbon capture and mass afforestation may also emerge as part of the solution to the mounting crisis. The sectors that may face headwinds are fossil energy, transportation, legacy agriculture & mining and non-circular consumption.
Climageddon: did you know?

- Humanity is currently using 1.75x more biological resources than our planet’s ecosystem can regenerate.1
- Around 30% of the world’s population is exposed to deadly heat levels for at least 20 days a year. 2
- Climate change will cost 3.2% of GDP by 2030, up from 1.6% today (US$1.2tn).3
- The global apparel textile industry has a higher carbon footprint than airlines and shipping combined.4
- 87% of countries could power themselves with renewables using <5% of their land. Yet 2019 global renewable funding rose only 1% y-y, indicating incation.5
- Sending 20 emails a day over a year creates the same emissions as a car travelling 1,000km.6
- Concrete is responsible for 4-8% of the world’s CO2 emissions, which is more than airlines.7
- Eating 1kg of steak is equal to using 16k litres of water (3.5 months of showers).8
- The past five years were the hottest since records began...the 20 warmest years on record were in the past 22 years.9
- A group of the world’s biggest companies with c.US$17tn market cap values the climate risks to their businesses at almost US$1tn.10
- Having one fewer child avoids emissions equivalent to 36 transatlantic round-trip flights.11
- Agriculture is causing more damage to oceans than plastic – the cost of excess fertiliser run-off into the oceans is US$200-800bn.12
- Every 1C rise in temperature could increase E. coli-caused diarrhoea by 8%.13
- In a no-climate-action scenario the average US citizen would lose about 10% of their income by 2100 while global GDP per capita would fall by 7.2%.14
- Air pollution kills 7 million people each year, costing US$5tn/year.15
- Australian bushfires have burnt an area greater than the size of Portugal since September (97k km²) and emitted 2/3rds of the nation’s annual carbon emissions compared with a normal year.16
- Canada is warming at 2x the global average, while Indonesia is planning to move its capital from Jakarta inland due to rising sea levels and increasing floods.17

Climate Change will define the 21st century

The 2020s – “Make-or-Break” decade for climate action

Why the 2020s? Because at the current pace, the carbon budget to 1.5°C warming would be exhausted by 2030 leading to catastrophic warming long term, extreme impacts for life on earth (e.g. extreme weather, mass migration, conflict) and trillions of dollars of economic losses (3.2% GDP risks by 2030). If climate change is not tackled aggressively this decade, it may be too late. Towards the end of the last decade, we got a glimpse of climate change impacts, especially the record wildfires in California, the Amazon, the Arctic and Australia. But impacts will get much worse as even a small rise in warming, such as 2.0°C rather than 1.5°C, magnifies climate risks materially.

Technology could solve some issues: Key cleantech solutions like renewables, electric vehicles and energy storage are now viable. 87% of countries could power themselves with cheap renewables using less than 5% of their land. Moonshot tech like climate-controlled farming, meatless meat, electric flight and geoengineering are on the horizon.

But human behaviour needs to change: Technology can cut emissions in energy and transport but behaviour change in food (less or no meat), travel (public transport and trains vs. flights) and consumption (re-use, repair, live with less, local) is also vital.

And policy needs to ramp up...exponentially: Humanity needs to move aggressively to a low carbon economy in the 2020s. “Net Zero by 2050” should really be “Net Zero by 2030” – better to “aim high, fall short” than “aim low, surely fail” on climate, we believe. Younger generations are to lead policy change through their activism and life choices.

Clean economy opportunity: A big transition to tackle the climate crisis will adversely affect the fossil fuel ecosystem but also create multi-trillion-dollar opportunities.

Six must-know aspects of climate change

Exhibit 1: Six must-know aspects of climate change
# 1 Global Risk (actually the Top 5 risks all climate related)

For the first time, the World Economic Forum (WEF) highlights climate-related risks not only as its top risk, but also all of its top 5 risks. Extreme weather is now the #1 global risk in terms of likelihood. Further, climate action failure, natural disasters, biodiversity loss, and human-made environmental disasters are risks #2 to #5 (source: WEF 2020). Climate change is the ultimate risk multiplier, where environmental risks are linked to societal stresses.

Exhibit 2: All 5 top likelihood risks are environmental

The WEF 2020 Top risks

Exhibit 3: WEF 2020 Global Risks

Source: World Economic Forum
**Trillions at risk from climate impacts & transition**

Climate change could cost US$54-69tn by 2100 in a scenario where we manage to limit temperature rise to 2°C (source: Moody’s). While for most people, 2100 will seem far away, the reality is that costs are already impacting individuals today. For the US, for instance, billion dollar climate events already cost US$300-500bn every five years (source: NOAA). And this is just extreme weather events – it excludes negative externalities such as ongoing economic losses in affected areas. Further costs will come from ocean acidification, aquifer salinization, heat-related productivity losses, human climate migration, and loss of biodiversity, among others. The value at risk from inaction could be $4.2tn vs. the world’s current stock of manageable assets of US$143tn (Source: Economic Intelligence Unit).

**Chart 1: Costs of $1bn+ natural disasters in the US**

<table>
<thead>
<tr>
<th>Year Period</th>
<th>US$bn Costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>1990-1995</td>
<td>$176bn</td>
</tr>
<tr>
<td>1996-2000</td>
<td>$94bn</td>
</tr>
<tr>
<td>2001-2005</td>
<td>$368bn</td>
</tr>
<tr>
<td>2006-2010</td>
<td>$143bn</td>
</tr>
<tr>
<td>2011-2015</td>
<td>$279bn</td>
</tr>
<tr>
<td>2016-2019</td>
<td>$506bn</td>
</tr>
</tbody>
</table>

Source: NOAA, NCDC

**Not just environmental, also a human & societal problem**

On top of the environment, economic and health-related problems, we believe climate change could translate into demographic, social, and political challenges the likes of which we have never seen before. Migration, poverty and inequality could be exacerbated by climate change (e.g. 143mn climate “migrants/refugees” by 2050) which will put more pressure on governments and political systems and further drive “peak globalization” and the rise of the state. On the positive side, the climate problem, solutions and public opinion are converging to make the 2020s the “decade of delivery” for climate action. Gen Z like Greta Thunberg are particularly aware of the climate risks, as highlighted by their activism in driving many niche green trends (e.g. flight shaming, veganism). Although these trends may not curb emissions significantly they will still likely influence government policy and attitudes towards carbon-intensive industries.

**Exhibit 4: Cross border migration flows from climate events**

Source: Overseas Development Institute. *ND-Gain Country Index measures a country’s vulnerability to climate change in combination with its readiness to improve resilience. The lower the number, the more vulnerable the country with possible scores ranging from 0 to 100.*
ESG: climate change is #1 issue
According to US SIF, the Forum for Sustainable and Responsible Investment, climate change is the single most important ESG issue considered by US asset managers, with US$3tn of assets using climate change and carbon footprint as one of their ESG criteria in their investment decisions. The CDP (Climate Disclosure Project) highlighted an analysis of 500 of the world’s biggest companies by market capitalisation, where 215 provided estimates of the potential financial implications for a proportion of their reported climate risks. Based on those estimates, US$970bn could be at risk within the next five years. And according to The Deloitte Global Millennial Survey 2019, both millennials and Gen Z identify climate change as the biggest challenge facing society today.

Exhibit 5: Top Specific ESG Criteria for Money Managers 2018

<table>
<thead>
<tr>
<th>Category</th>
<th>Criteria</th>
<th>Trillion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Climate Change/Carbon</td>
<td></td>
<td>$3.00</td>
</tr>
<tr>
<td>Tobacco</td>
<td></td>
<td>$2.89</td>
</tr>
<tr>
<td>Conflict Risk (Terrorist or Repressive Regimes)</td>
<td></td>
<td>$2.26</td>
</tr>
<tr>
<td>Human Rights</td>
<td></td>
<td>$2.22</td>
</tr>
<tr>
<td>Transparency and Anti-Corruption</td>
<td></td>
<td>$2.22</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Percent Increase in Assets Affected since 2016</th>
</tr>
</thead>
<tbody>
<tr>
<td>110%</td>
</tr>
<tr>
<td>432%</td>
</tr>
<tr>
<td>47%</td>
</tr>
<tr>
<td>171%</td>
</tr>
<tr>
<td>206%</td>
</tr>
</tbody>
</table>

Source: US SIF Foundation

Exhibit 6: The European Green Deal

Source: European Commission, Europa
Climate mitigation market ~2x by 2030 to >$2tn annually

The climate mitigation market is expected to double by 2025 to over $2 trillion annually (>2% of global GDP). Clean energy, biofuels, efficiency and electrification of transport are some of the major climate mitigation markets. Support is expected from policies, such as the EU’s proposals for at least €1tn investments for the planned EU Green Deal.

Exhibit 7: Trillions of dollars of opportunities annually to help mitigate climate change

<table>
<thead>
<tr>
<th>Climate mitigation annual market</th>
<th>2018</th>
<th>2025</th>
<th>CAGR</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$1.25 tn pa</td>
<td>$2.34 tn pa</td>
<td>9.4%</td>
</tr>
</tbody>
</table>

**European Green Deal’s Investment Plan**
At least €1 trillion (European Commission)

**Global Clean Energy Investments in 2021-30**
$3.8 trillion (2018 real, BNEF)

**Annual Investments Needed For Climate Goals**
$1.6 to 3.8 trillion pa (Climate Policy Initiative)


Decarbonization – Emission Impossible?

Scale solutions like renewables, electric vehicles and energy storage can be accelerated quickly with the right incentives and help tackle a large share of emissions. But clean airplanes/shipping, meat alternatives and geo-engineering will be needed and given these are still niche, more R&D support is key. Emerging markets, where emissions are growing faster, will need to be helped by developed nations that have polluted more in the past. Bridge fuels like natural gas and higher carbon pricing could also be key.

Exhibit 8: Current solutions to climate change

<table>
<thead>
<tr>
<th>Wind</th>
<th>Solar</th>
<th>Future &amp; Electric Mobility</th>
<th>Energy Storage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Addresses &gt;40% of CO2 emissions</td>
<td>Addresses &gt;40% of CO2 emissions</td>
<td>Addresses &gt;20% of CO2 emissions</td>
<td>Addresses &gt;40% of CO2 emissions by boosting renewables</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Waste to energy</th>
<th>Sharing economy</th>
<th>Electric planes</th>
<th>Reforestation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Addresses &lt;5% of GHG emissions</td>
<td>Improves utilisation</td>
<td>Addresses 2-3% CO2 emissions from air travel</td>
<td>Huge potential &amp; cost effective CO2 abatement solution but works over time</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Circular Economy</th>
<th>Sustainable packaging</th>
<th>Local production</th>
<th>Less Meat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Could address part of 45% non-energy GHGs</td>
<td>More pollution issue but also GHG benefits</td>
<td>Addresses GHG from shipping &amp; EM</td>
<td>Addresses &gt;20% of GHG emissions, meat industry uses huge resources</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Smart cities</th>
<th>Green investing</th>
<th>Carbon offsetting</th>
<th>Carbon pricing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Addresses emissions from rising urban population (~70% by 2030)</td>
<td>Needed to fund multi-trillion cleantech capex</td>
<td>Solutions for areas lacking clean options now</td>
<td>May target large portion of GHG emissions if more sectors included</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Remote working</th>
<th>Energy efficiency</th>
<th>Future Farms</th>
</tr>
</thead>
<tbody>
<tr>
<td>Technology to reduce commuting &amp; flying</td>
<td>Touches on most emission aspects by reducing usage</td>
<td>Addresses &gt;20% of GHG emissions, Tech enhances efficiency by order of magnitude (greenhouses, vertical, precision)</td>
</tr>
</tbody>
</table>

Source: BofA Global Research
Impact is reaching boiling point

Extreme weather events are intensifying worldwide
The incidence of extreme weather is rising worldwide in its many forms such as tropical storms, droughts, heatwaves, floods, wildfires and extreme cold, among others. 40% of US cities were affected by some form of extreme weather in 2018 compared with only 15-20% over the 20th century (5-year rolling average) (source: NOAA).

Chart 2: US Climate Extremes Index (CEI) up sharply in recent decades, almost 40% of US areas affected by extreme weather in recent years

Chart 3: Cost of US extreme weather has been rising - costs in 2016-2018 (3 years) more than any 5-year period after 1990

Chart 4: US$763bn cost of US extreme weather in 2010-18, storms 77% of total

Storms caused 77% of economic damage from US extreme weather
Storms are among the biggest impacts of climate change already causing significant economic damage. Tropical sea storms (hurricanes) and land storms (e.g. tornadoes), were the leading cause of economic damage in the US due to extreme weather (77% of total costs in 2010-18) (source: NOAA).

7 of the 20 most expensive storms since 1990 were in 2017-19
The intensity of storms has been increasing in recent years as the oceans heat up. For example, of the 20 most-expensive tropical storms since 1990 in the Americas and Asia, seven were in 2017-19 alone underlying that the level of damage is intensifying as temperatures rise and storms become more potent (source: NOAA).
Exhibit 10: Most expensive tropical storms – 10 in US and 10 in Asia - 7 out of 20 were after 2016

Source: Data from Wikipedia, Statista, NOAA, RoA Global Research graphic

Over 800m people at risk from rising sea levels by 2050
According to the U.S. Environmental Protection Agency (EPA), sea levels have risen 6-8 inches (15-20 cm) in the past 100 years. By 2050, more than 570 low-lying coastal cities will face projected sea level rises of at least 0.5 meters. This would put >800 million people at risk from the impacts of rising seas and storm surges including 20+ locations worldwide each with 10 million + populations (source: C40 Cities).

Exhibit 11: Coastal cities at risk from sea level rise by 2050 (20+ cities at risk with >10 million population each)

Source: C40.org

Cities: moving inland
In August 2019, Indonesia announced it will be relocating its capital from Jakarta to a new city in Borneo. The transition is expected to take 10 years and cost US$34bn. Jakarta is a huge metropolis with 10 million people (30 million in wider area) but has been sinking for decades due to rising sea levels and ground water extraction. Jakarta would be the first major metropolis worldwide to be moved due to climate change. It is also among the fastest-sinking cities (c.10 inches a year, as per EcoWatch).
Many more regions showing 2.0°C warming now vs. three decades ago
In the past five years, many more regions globally have seen almost 2.0°C warming vs. pre-industrial levels compared with the early 1990s, indicating more warming over land.

Exhibit 12: Almost no global regions saw c. 2.0°C warming in 1991
Source: NASA

Exhibit 13: Many global regions saw c. 2.0°C warming in 2014-18
Source: NASA

July 2019 hottest on record – but record set to be broken given warming trends
July 2019 was the hottest in 140-year records according to NOAA, surpassing a previous record from July 2016. Given high temperatures, average Arctic sea ice set a record low in July 2019 – 19.8% below average. July 2019 was also the 43rd consecutive July and 415th consecutive month with above-average global temperatures. Given consistent warming, 2019’s records are likely to be broken soon. Almost 400 all-time high temperatures were set in the northern hemisphere in summer 2019, according to an analysis of temperature records (source: BBC, Berkeley Earth).

Exhibit 14: Loss of productivity in the US due to heat
Source: UN

Exhibit 15: Hot 2019 in Europe (35-45 °C in many regions)
Source: NASA

Heat stress spike predicted to cost global economy US$2.4tn a year
Heat stress at work linked to climate change is set to have a big impact on productivity and economic losses, notably in agriculture and construction. The total cost of these losses could be US$2.4tn every year due to just 1.5°C warming by 2100 (source: International Labour Organisation).

Loss of ice has been accelerating with Greenland contributing the most
Ice loss at the poles has been getting worse in the past few decades and as global warming continues, loss of ice will accelerate. Since 1979, Arctic minimum sea ice levels (September) have been decreasing by as much as 13.7% per decade (NASA). In contrast, Antarctic sea ice was increasing up until 2014-15, however, there still has been a sudden drop in recent years and continued melting of the ice sheet.
Chart 5: Antarctic Sea Ice levels at lows in recent years

Source: NASA data, BofA Global Research graphic, NB: Data approximated from NASA graph

Mass loss from the Antarctic ice sheet in 2007-16 tripled vs. 1997-2006 and for Greenland, doubled over the same period (source: IPCC 2019). Greenland is contributing more to sea level rise currently due to faster melt in the North Pole vs. the South Pole. But longer term, the Antarctic is expected to have a much bigger impact on sea levels due to warming given the sheer volumes of ice in the region. The global mean sea level (GMSL) rise is projected to be 0.43m (0.29-0.59m, likely range) in 2100 under RCP2.6 and 0.84m (0.61-1.10m, likely range) under RCP8.5 (RCPs or Representative Concentration Pathways are the IPCC’s scenarios for different levels of warming).

Wildfires intensifying due to warming, heatwaves and deforestation

Wildfires have been in increasing focus in the past two years with high-profile devastating fires in California (2018), the Amazon (2019), the Arctic (2019) and Australia (record bushfires in 2019/2020), especially as their frequency and intensity increased in recent years. This is partly due to higher temperatures or even heatwaves drying out forests, making them more vulnerable to wildfires. In deforestation, trees are cut down and left to dry, making them more susceptible to fire later. There are other causes like warmer weather increasing the number of pests that kill trees, which also makes them more likely to catch fire.
Water scarcity likely to worsen due to warming, ice melt and heatwaves

By 2025, 1.8 billion people will be living in countries or regions with absolute water scarcity, and two-thirds of the world’s population could be living under water-stressed conditions. Under the existing climate change scenario, almost half the people in the world will be living in areas of high water stress by 2030 (source: UN).

Exhibit 18: Water stress could be a major issue by 2040

37 countries face “extremely high” levels of water stress, i.e. that >80% of water available to agricultural, domestic, & industrial users is withdrawn annually (source: WRI).

Exhibit 19: US water stress 2010

Exhibit 20: US water stress 2019
Spillover: it’s not just an environmental problem anymore

Peak Globalization: fanning the geopolitical flames
Climate change-induced resource scarcity and the economic disruption from shifts in traditional industries and migration waves could be key contributors to “peak globalization”. This will further exacerbate the on-going curtailment of the free movement of goods, capital, knowledge, people and information between countries. Furthermore, geographical regions reliant on crude exports and facing “peak oil” in carbon-intensive sectors could be disrupted and face major job losses. As a result, any carbon-reductive policies that enable the transition towards a cleaner economy might come at the expense of economic growth, at least in the short term. Ultimately the spillover effects of climate change could result in governments facing further challenges from the rise in populism and polarisation.

Migration: climate refugees/migrants on the rise
Climate change also has a direct impact on the movement of people owing to extreme weather-induced migration. To put the potential problem into perspective, 40% of the US population today lives in coastal areas that may be vulnerable to rising sea levels (source: NOAA). 143mn climate migrants / refugees are expected by 2050, coming from regions such as LatAm, Sub Saharan Africa and South Asia alone (source: World Bank). And 17.2mn were forced to leave their homes in 2018 as a result of natural disasters, such as flooding and desertification. The Philippines, China and India accounted for around 60% of all new displacements, mostly in the form of evacuations (source: UN).

“Land in Asia is home to 3/4 of the world’s population at risk from rising sea levels affecting coastal regions” (source: Climate Central)
The impact of rising sea levels and flooding impacts both EMs and DMs. China is the #1 country at risk in the Climate Central study, with 145mn citizens currently living on land at risk of being submerged. India, Bangladesh, Vietnam and Indonesia were the second to fifth countries most at risk, respectively, with more than 10mn in danger of flooding. Asian global megacities with the top-10 largest threatened populations include Hong Kong, Shanghai, Kolkata, Mumbai, Dhaka, Jakarta, and Hanoi (source: Climate Central). However, DMs such as the US also face the threat of rising sea levels. According to the US EPA, sea levels have risen 6-8 inches (15-20cm) in the past 100Y. By 2050, over 570 low-lying coastal cities will face projected sea level rises of at least 0.5m. This would put >800mn people at risk from the impacts of rising seas and storm surges, including 20+ locations each with 10mn+ populations (source: C40 Cities).

**Poverty: the “bottom billions” are impacted the most**
Rising global temperatures and extreme weather are set to impact 60% of the world’s population, mainly from low-incomes countries. For these regions, higher temperatures lowers output per capita by reducing agriculture output, suppressing worker productivity, slowing investment, and damaging health (source: IMF 2017). Overall 100mn people could be pushed into poverty because of climate change effects by 2030E (source: Global Commission on Adoption). In a scenario of unmitigated climate change (RCP 8.5), per capita GDP in low-income countries would be 9% lower in 2100 than it would have been without the temperature increases (source: IMF 2017).

**Exhibit 25: Effect of a 1C increase in temperature on real per capita output at the country level rescaled in proportion to total population**

Source: IMF 2017

**Exhibit 26: Climate change effect on per capita GDP in 2100 by country**

Source: Brookings Institution 2019
Inequality: ‘cold countries get richer, hot get poorer’

Unmitigated climate change could also increase global inequality. A study by the University of California, Berkeley found that climate change on a relative basis is generally good for cold countries which tend to be richer, but more harmful for hot countries which tend to be poorer (source: Burke, Hsiang & Miguel 2015). Further studies show that economy productivity peaks at about 13°C-15°C, with economic activity dampened at higher temperatures. Advanced economies have annual average temperatures close to this threshold. EM economies and low-income developing countries tend to be concentrated in hotter climates. For the median emerging market economy, a 1°C increase from 22°C lowers growth in the same year by 0.9 percentage points. For the median low-income developing country with a temperature of 22°C, a 1°C increase reduces growth by 1.2pp (Source: IMF 2017).

Exhibit 27: Change in global GDP per capita by 2100E vs. a world without climate change

Source: Burke, Hsiang & Miguel (2015)

Fertility: hotter weather and lower birth rates

Increased temperatures due to climate change may also reduce population growth rates in the coming century. This is because rising temperatures could mean diminished coital frequency and thus fewer babies, according to researchers at the National Bureau of Economic Research (NBER). Having estimated the effects of temperature shocks on birth rates in the US between 1931 and 2010, they found that extra days above 80°F cause a decline in birth rates approximately eight to 10 months later. Overall climate change will shift even more births to the summer months when third trimester exposure to dangerously high temperatures increases (source: Barreca et al, NBER).

The NBER study estimates that a single additional hot day above 80°F, relative to one day between 60°F and 70°F, causes a 0.4% decrease in birth rates nine months later (or a reduction of about 1,165 births across the whole US). Hence, the study projects a scenario in the US between 2070E and 2099E where it may have 64 more days above 80°F per year than the three in the baseline period from 1990 to 2002. The result is a potential 2.6% decline in the US birth rate, or 107,000 fewer babies a year.

Exhibit 28: Effect of daily mean temperature >80°F relative to 60-70°F on log birth rate

Source: Source: Barreca et al, NBER Oct. 2015
Activism: driving policy and capital
Climate Change is a key agenda item for political parties, consumers and corporates in the 2020s
Climate change is starting to become a key agenda item in politics (e.g. US Democratic Primaries 2019, Greens gaining in Europe), among consumers (veganism, anti-plastic, flight shaming) and for corporates (100% clean energy goals, circular economy focus). Climate activism is on the rise, e.g. Greta Thunberg’s climate strike movement, Extinction Rebellion protests, etc. In some cases, activism can be even more extreme, e.g., Heathrow Pause aims to use drones to halt flights and cut CO2. Climate Action could be one of the biggest transformations of the global economic landscape, impacting current practices in many areas, such as energy, farming, transport and even globalisation/consumerism (local production, sharing, less fast fashion). Emission regulations are becoming tougher, e.g., renewable targets, carbon pricing, charges for high-polluting vehicles and airline taxes, which will drive major change.

To put the public shift into perspective, by the widest margin since 2000, more Americans now believe environmental protection should take precedence over economic growth when the two goals conflict more. 65% now choose the environment, while 30% choose the economy (source: Gallup). Furthermore, use of the term “climate emergency” was 100x more common in 2019 than the previous year (source: Oxford Dictionary, WEF), as people around the world increasingly directly feel the effects of the climate crises, e.g., Australian bushfires, Amazon and California wildfires etc.

Impact Investing, ESG & Green Financing major forces
There is now a growing pool of investments for cleantech in equity (ESG, impact, thematic) and debt (e.g. green bonds). ESG is one of the fastest-growing capital pools globally, with the environment being one of the key drivers in ESG.

Exhibit 29: Activism, Policy & Clean Finance to accelerate drive towards clean technologies & solutions
Major geopolitical issues, from Consumer to Circular

Bold climate action could dramatically alter the global geopolitical balance. A fast transition to electric vehicles could impact or even destabilise oil-sensitive economies. A renewables surge could affect regions dependent on coal & gas exports, while a shift to more vegetarian diets could impact farming and the political landscape globally (similarly to how manufacturing job losses influenced politics in recent years). There could be a shift from the consumption model of recent decades (a key GDP driver) to a circular and more sustainable model (sharing, eco-friendly and frugal), pointing to lower growth.

General electorate starts to care about climate change

The reason politicians are starting to become more aware about and act on climate change (via new legislation or targets) is the rising importance of the issue among the electorate. Moves from centrist political stances to more extremes, both on the right and left, have also led to greater acceptance of “Green” politics or views.

Chart 11: About 13% swing towards accepting or being worried about climate issues between 2013 and 2018 (sizeable swings in 2018)

<table>
<thead>
<tr>
<th>Political Group</th>
<th>2013</th>
<th>2018</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conservative Republicans</td>
<td>14%</td>
<td>32%</td>
</tr>
<tr>
<td>Liberal/Moderate Republicans</td>
<td>54%</td>
<td>56%</td>
</tr>
<tr>
<td>Moderate/Conservative Republicans</td>
<td>61%</td>
<td>80%</td>
</tr>
<tr>
<td>Liberal Democrats</td>
<td>61%</td>
<td>95%</td>
</tr>
<tr>
<td>All Americans</td>
<td>53%</td>
<td>69%</td>
</tr>
</tbody>
</table>

Worried about Global Climate Change (% across political spectrum)

- I have already experienced its impact: 33% (2013), 40% (2018)
- It will harm me personally: 38% (2013), 49% (2018)
- It will harm Americans: 53% (2013), 65% (2018)
- I am worried about it: 53% (2013), 69% (2018)
- Its important to me personally: 55% (2013), 72% (2018)
- I think most scientists agree its human caused: 42% (2013), 62% (2018)
- I think its happening: 69% (2013), 73% (2018)

Source: Climate Change Communication, BoFA Global Research graphic, NB: data from 11 national surveys (n=13,103) from Nov 2013 to Dec 2018

Niche green trends gain traction = impacting all sectors

Many niche green trends are gaining traction, especially among younger generations but increasingly even in wider demographics, helped by social media and streaming entertainment. These trends have sustainability, climate change, health and less resource use at their core. Niche green trends may not curb emissions much but they influence policy and attitudes towards high-emitting industries (e.g. energy, transport).

While much of the climate activism has been directed through more niche topics, such as plastics and flights, overall climate awareness and growth may see action in other more traditional consumer practices, ranging from transport to energy, where in Europe 27.2% of energy was consumed by households in 2017 (source: Eurostat 2019).

- **Less/no meat or animal products:** There is a growing trend towards reducing consumption of meat or animal products (milk, leather), or even becoming vegan. Health benefits, animal welfare and the climate impact are key reasons for the shift.

- **Meat substitutes:** Start-ups are trying to commercialise meat substitutes, ranging from vegan burgers and plant-based burgers that taste/feel like meat to even lab-grown meat. Already some major fast food chains are sourcing meat substitutes.
• **Ride pooling & micro mobility**: This ranges from not owning a car and using ride hailing to ride pooling (e.g. sharing an Uber/Lyft) and micro mobility (scooters, bikes) to reduce carbon footprint, save on costs and gain health benefits.

• **Flight shaming, train bragging**: An emerging trend towards reducing flights taken to curb personal CO2 emissions. This is catching on, particularly in Sweden, helped by Greta Thunberg’s climate change movement, with new Swedish terms, such as flygskam (flight shame) and tägskryt (train brag) gaining popularity. Air travel has grown almost every year since 1990 and changes in consumer behaviour are key to cutting this growth. In Europe, there are plans to revive overnight sleeper trains.

• **Ethical fashion**: The global apparel/textile/fashion industry has a higher carbon footprint than airlines and shipping combined. As a result, climate-conscious consumers are looking at more sustainable options, such as renting, used clothes, fewer purchases, longer-lasting high-quality, natural fibres, local production, etc.

• **Corporate CO2 curbs**: Corporates are starting to focus on CO2 and their climate footprint. Some tech companies are procuring (or planning to procure) 100% of their energy from renewables but climate measures go beyond this into recycling, the circular economy and product design/materials, even tracking the executive CO2 footprint. There are now even “net-negative” emission targets by 2030.

• **Climate-controlled farming**: Climate-controlled farming in its many forms, like vertical farms, greenhouses or hydroponics, is much more efficient than traditional farming (yield, resource use). Energy-use challenges can be solved by cheap abundant renewables. There is growing interest in this area, primarily to reduce climate risks.

• **Local production**: Climate-conscious consumers are starting to choose locally grown or produced food/goods over imported, to reduce their climate footprint.

• **Right to repair**: Repairing gadgets/machinery to prolong life is gaining momentum, with rules likely to be supportive (e.g. EU proposals on right to repair). Even community movements around repair & reuse are emerging (e.g. Restart project).
Climate Costs: US$69tn by 2100

US$54-69tn climate costs by 2100

Different published analysis point to varying climate change impacts, but all show large impacts. As per Moody’s, if the average global temperature soars to 1.5°C above pre-industrial levels – the lower limit of the Paris climate agreement – the cost to the global economy is estimated to be US$54tn in 2100 but under a warming scenario of 2°C, the cost could reach US$69tn. Global annual cost could reach US$5.7tn by 2100 according to the American Geophysical Union. In contrast, the Economist estimates value at risk (VaR) due to climate change at US$4.2tn, or 3% for private investors (up to US$13.8tn in extreme scenarios), while the OECD estimates US$6.9tn as annual spend required to meet climate and development objectives for 2030, indicating an unprecedented transformation of current systems. Global warming could cut global GDP by up to 7.5% by 2050 (Oxford Economics) while unmitigated warming could reduce global incomes by ~23% by 2100, widening income inequality (Burke, Hsiang, and Miguel, 2015).

But costs already ongoing, especially due to extreme weather

For most people, 2100 might seem far away, but climate change is already costing billions of dollars today. In the US alone, climate events cost US$300-500bn every five years, with over 70% of this due to storms. And this excludes externalities such as ongoing economic losses in affected areas. As per research from DARA/CVF, climate change will cost 3.2% pa of GDP by 2030, up from 1.6% pa today (US$1.2tn).

Chart 12: Cost of California Wildfires in 2017-18

Source: The Balance, Bustle.com, Cal Fire, BofA Global Research graphic

Chart 13: Costs of US$1bn+ natural disasters in the US: Share by type since 2000

Source: Data from National Climatic Data Center (NCDC) and National Oceanic and Atmospheric Administration (NOAA), BofA Global Research graphic

Chart 14: Costs of US$1bn+ natural disasters in the US: US$bn costs since 1990

Source: National Climatic Data Center (NCDC) and National Oceanic and Atmospheric Administration (NOAA), BofA Global Research graphic
Storm surge, coastal erosion and aquifer salinization: >€6bn pa by 2020 in EU
Rising sea levels and more intense tropical storms are likely to increase the risks of storm surges, coastal erosion and salinization of aquifers. Given that more people live near coastal regions, the impact from climate change on these areas is expected to be more pronounced. The cost of doing nothing against the effects of climate change in Europe’s coastal areas could be >€6bn pa by 2020 (source: European Commission). In the US, ~US$400bn of investments are estimated to be needed to combat rising seas and worsening storms in the coming decades (source: Center for Climate Integrity). More intense heat and urbanisation have also led to increased use of groundwater resources, leaving coastal areas at risk from salinization. Salt contamination, which leads to stunted and uneven plant growth, is already estimated to affect 20% of cultivated land worldwide (source: Science Direct).

Ocean acidification and loss of corals: US$1tn cost annually by 2100
Ocean acidification will cost the world economy more than US$1tn annually by 2100, (source: UN). The oceans absorb the majority of the carbon emissions from human activity, leading to acidification. They also absorb the majority of the heat from the greenhouse effect, leading to coral bleaching. Changing the composition of the world’s oceans will undermine various marine ecosystems, including commercial operations (source: UN Convention on Biological Diversity). For example, shellfish find it harder to form and maintain their shells in more acidic waters.

Risks of human migration, conflicts and unrest: 25mn-1bn eco migrants by 2050
There are currently 64mn forced migrants in the world fleeing wars, hunger, persecution and a growing force: climate change. The UN estimates that there could be anywhere between 25 million and ~1bn environmental migrants by 2050 (source: UN International Organization for Migration). Further, climate change could result in 143 million people becoming “climate migrants”, escaping crop failure, water scarcity, and rising sea levels, especially in Sub-Saharan Africa, South Asia, and Latin America. However, reducing greenhouse gas emissions and “robust development planning” could reduce the number of “climate migrants” by 80% to 40 million people (source: World Bank 2018).

Loss of biodiversity and risk of crop failure: €14tn cost by 2050
Current extinction rates are 100 to 1,000 times higher than in pre-industrial times. The rate exceeds 100 extinctions per million known species and, unless decisive action is taken, this could increase tenfold over the course of the century (source: Erik Gómez-Baggettun, Berta Martín-López, Madrid University). The International Union for Conservation of Nature (IUCN) estimates that 12% of bird species, 23% of mammals, 32% of amphibians and 25% of coniferous plants are currently endangered. According to a European Commission report, the estimated annual loss in ecosystem services resulting from the cumulative loss of biodiversity will be nearly €14tn by 2050.

Change in ocean currents could impact weather patterns: risk to W. Europe
Gulf Stream ocean currents are crucial in controlling global climate and the system today is at its weakest recorded levels. The Atlantic Ocean current system (Amoc) has weakened by 15% since 1950, due to melting Greenland ice and ocean warming making sea water less dense and more buoyant. Past collapses of the giant network have caused some of the most extreme impacts in climate history, with Western Europe particularly vulnerable to a descent into freezing winters. A significantly weakened system is also likely to cause more severe storms in Europe, faster sea level rises on the east coast of the US and increasing drought in the Sahel in Africa. Scientists warn that during the last Ice Age, winter temperatures changed by up to 10°C within three years in some places due to changes in ocean currents. Changes in the Amoc system could also lead to Europe experiencing heatwaves (as seen in recent years) and faster ice melt in Greenland (currently melting at the fastest rate in 450 years) (source: Potsdam Institute of Climate Impact Research).
Inaction: so much to do...so little done
Climate action disappointing so far...

Overall efforts to reduce emissions and at least delay climate risks have been limited so far.

Exhibit 32: Missing Action – response to climate change still not meaningful despite rising rhetoric

- Rise in fossil fuel production: vs. 2008, annual fossil fuel production (and emissions) were higher in 2018 (oil/coal +c.15%, gas +c.28%). EM (esp. China) drove this growth but DM is flat rather than down.

Source: BNEF, BP, ICAO, WRI, Inside EVs, FAO, Our World In Data, BoFA Global Research

**Chart 15: Powergen CO2 emissions not expected to fall due to rising power demand, esp. EM**

Source: Bloomberg NEF NEO 2019 outlook data, BoFA Global Research graphic

**Chart 16: Oil demand does not fall much by 2040 in some scenarios**

Source: BNEF 2019 EV outlook, International Energy Agency (IEA), BoFA Global Research graphic, * New Policies Scenario assumes electrification but EM/trucks/petro-chem demand grows, ** SDG scenario sees climate action limiting oil demand but impact more by 2040. mmpd = million barrels per day

**Chart 17: Global natural gas demand likely to grow as per long-term outlooks**

Source: Wood Mackenzie, 2019 Energy Transition, International Energy Agency (IEA), BoFA Global Research graphic, * New Policies Scenario assumes strong EM gas growth for clean air, ** SDG scenario sees climate action limiting demand but not much impact on demand, bcm = billion cubic meters
- **Market outlooks for fossil fuel do not show much demand decline by 2040:** from current levels, and even indicate rising demand for gas.

- **Low electric vehicle share:** Transition to clean transport has been slow we believe in passenger electric vehicles as represented by only c.2% of 2018 annual sales being EVs (source: Inside EVs). The proportion of commercial EVs is even lower.

- **Absolute fossil power generation up despite renewables:** despite attractive economics for renewables now, absolute power generation from fossil fuels was still >10% higher in 2018 vs. 2008 (mostly in China/India).

- **Air passenger miles almost 2x 2008 levels:** consumers are flying more every year, especially in EM. Air travel is now >2% of total CO2 emissions, among the fast-growing categories and with limited alternatives so far.

- **Meat consumption rising unabated, 2x vs. 1990 levels:** but animal protein is particularly emission heavy relative to plant-based options. About 36% of global crop calories go to feed animals (67% in the US) but 100 calories of grain produce just 12 calories of chicken or 3 calories worth of beef.

- **High rate of deforestation:** 83% of agricultural land is used for livestock and growing feedstock for livestock. In contrast, livestock only contributes 18% of caloric supply for global consumption. Currently, we use c.50% of vegetated land for agriculture land globally. At current rates we could lose forested area 2x the size of India by 2050 (source: UN FAO 2017, Poore, Nemecek, Science 2018, WEF, WRI).

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**Exhibit 33:** We already use 50% of habitable land for agriculture and yet we will need 56% more food for 2050...

<table>
<thead>
<tr>
<th>Area</th>
<th>2010</th>
<th>2050</th>
</tr>
</thead>
<tbody>
<tr>
<td>Earth’s surface</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Land surface</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Habitable land</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Agricultural land</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Livestock</td>
<td>83%</td>
<td>83%</td>
</tr>
<tr>
<td>Food eaten for global consumption</td>
<td>12%</td>
<td>12%</td>
</tr>
<tr>
<td>Source: UN, FAO 2017, Poore, Nemecek, Science, 2018</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Exhibit 34:** Creating a Sustainable Food Future by 2050

<table>
<thead>
<tr>
<th>How do we feed 10 billion people...</th>
<th>...without using more land...</th>
<th>...while lowering emissions?</th>
</tr>
</thead>
<tbody>
<tr>
<td>WE WILL NEED 56% more food</td>
<td>WE NEED TO PREVENT AGRICULTURE FROM EXPANDING</td>
<td>WE CAN LOWER EMISSIONS</td>
</tr>
<tr>
<td>56% more food</td>
<td>we currently use ~50% of the world’s vegetated land for agriculture</td>
<td>12x CO2, 67%</td>
</tr>
<tr>
<td>10B people in 2050</td>
<td>TO SAVE AN AREA OF FORESTS NEARLY 2X the size of India</td>
<td>4x CO2, 67%</td>
</tr>
<tr>
<td>Source: WEF, World Resources Institute</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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**But the solutions are not always clear**

While many solutions are coming about, it is clear that there is no silver bullet to solve climate change. All solutions come with their own problems, from disposal of electric vehicle batteries to the large quantities of polluting brine generated in the desalination process. Solving climate change will therefore need a collection of answers combined in a complex system.
CO2: getting worse before it gets better
Francisco Blanch
BofAS
francisco.blanch@bofa.com

How to decarbonise? Cleantech, carbon prices, nat gas
To cap GHG emissions from here, markets, tax policy, technology, politicians and society will need to come together with a magic formula. Decarbonization will likely require: (1) low nat gas prices and high oil, coal, and carbon emissions prices; (2) advances in battery and CO2 removal technology, (3) a social transfer from richer to poorer countries, and (4) a major shift in consumer preferences into less carbon intensive goods and services. Carbon policies need to target both stock (atmospheric concentration) and flow (annual emissions). There could be different carbon price scenarios to 2050, ranging from business-as-usual low prices to very high prices in an aggressive climate action case.

UK Net Zero targets may require carbon price of £50-160 per tonne - LSE
The London School of Economics (LSE) believe the cost of achieving net-zero in the UK will require higher carbon prices, so far under-priced in most sectors, stalling the development of low-carbon solutions. As per the LSE, the UK Government will have to adjust the shadow price of carbon – the price it uses internally to guide public-sector decisions. A shadow price consistent with net-zero would start at £50 (range £40–100) per tonne of carbon dioxide (tCO2) in 2020, reaching £75 (£60–140) in 2030 and £160 (£125–300) in 2050, reflecting cost of negative emissions technology.

In the past 200 years, humanity did not pay to pollute...
Global economic growth has historically been aligned with energy demand. To bring people to an economic production center (a city) or to move heavy machinery (a factory) requires a lot of energy. Conversely, as the economy tails off, jobs decline, factories shut down, people stay at home and energy demand falls. Since the industrial revolution energy demand growth has been largely met by hydrocarbons.

In turn much of the growth in global energy consumption has been fueled by hydrocarbons.

Chart 18: Global economic growth rates have historically been aligned with energy consumption...

Chart 19: ...and in turn much of the growth in global energy consumption has been fueled by hydrocarbons
...so carbon emissions rose substantially with industrialization
Global energy demand exploded in recent decades with industrialization and urbanization (~3x in past 50 years, ~10x in 100 years), with man-made carbon emissions increasing dramatically during this period. Without an economic penalty for pollution, businesses rushed to produce fuels that could deliver the fastest economic growth over the shortest economic period at the highest economic profit. The US shale revolution has further exacerbated the problem, as global Green House Gas (GHG) emissions have partly accelerated on rising US oil supplies and falling global energy prices.

To tame climate change, emissions need to be curbed...
One key way to curb GHG emissions is to make GDP and population growth less carbon intensive, for example in California, Japan, or even Europe. California’s GDP expanded by 53% in the past 20 years as population grew by 21%, while CO2 emissions dropped by 46%. Japan’s economy grow by 23% in the last 20 years but emissions fell 7%.

Annual emissions still rising even after the Paris Climate Agreement
Global emissions kept rising even after the 2015 Paris Agreement despite climate risk warnings – 2018 global CO2 emissions were >10% higher vs. 2010. Concentration of CO2 in the atmosphere crossed the critical 400ppm (parts per million) threshold in recent years (now ~410ppm) and this is only set to get worse in the coming decades.

Chart 23: Atmospheric CO2 concentration - the wrong kind of bull market
Atmospheric CO2 concentrations continue to rise unabated

Source: Data from NOAA (National Oceanic and Atmospheric Administration), Graphic from BofA Global Research
**IPCC's carbon budget for 1.5°C warming barely gets humanity to 2030**

According to IPCC data, humanity has only c.10-12 years left before exhausting the 1.5°C emissions budget but current 2030 national plans point to >2.0°C warming. In its 2018 report, the IPCC shows the remaining carbon budget to limit global warming to 1.5°C as 420 gigatons of CO2 or GtCO2 (@ 66% probability) and 580 GtCO2 (@ 50% probability) vs. current emissions of ~42 GtCO2 pa. All the IPCC’s pathways that limit warming to 1.5°C assume carbon dioxide removal (CDR) but such technology is not yet available (except reforestation). In reality, without drastic CDR or emission cuts, 1.5-2.0°C warming scenarios are at the optimistic end of possibilities.

**Exhibit 35: IPCC expects global warming of 1.5°C reached in 2040**

Source: IPCC AR15 Report October 2018 – Global warming of 1.5°C

**Chart 24: How many years of current emissions would use up the IPCC's carbon budgets for different levels of warming?**

Source: Carbon Brief data, BofA Global Research Graphic

**Chart 25: The remaining CO2 budget for 1.5°C warming would be over by around 2030 as per IPCC data on CO2 budget and annual emissions**

Source: data from IPCC (Intergovernmental panel on Climate Change) 2018, BofA Global Research graphic

**2.0°C warming may be already "locked in"**

Greenhouse gases (GHG) already in the atmosphere since 2007 may already have “locked-in” 2.0°C (source: climatechange2013.org, IPCC). But the warming effects of GHGs are delayed by 25-50 years (source: James Hansen et al 2005). Thus, observed warming by 2017-18 was only ~1.0°C due to this lag and, even if annual emissions fall to zero now, temperatures will keep rising owing to these accumulated GHGs. Since 2007, when 2.0°C was potentially “locked in”, emissions have accumulated even faster and will continue into the 2030s-40s, meaning more GHGs and pointing to >2.0°C warming long-term. The IPCC’s 2018 special report focused on 1.5°C warming, although various climate experts have criticised the IPCC in the media for leaving out worse scenarios and publishing a message that seemed politically acceptable. In IPCC’s 2014 report,
scenarios by 2100 pointed to mean warming of 1.8°C (RCP4.5), 2.2°C (RCP6.0) and 3.7°C (RCP8.5), which were well above the more benign 1.5°C 2018 scenario.

**Chart 26: Many warming scenarios exist, some significantly scarier than IPCC’s 1.5-2.0°C focus**

Source: IPCC Data, BofA Global Research graphic, * IPCC Central pathway is based on IPCC 2018 report 1.5°C warming by 2040 outlook and 3.0°C likely warming by 2100 under current 2030 national plans, i.e. without net negative emissions, # IPCC Harsh pathway is based on IPCC 2018 report lower bound timeline for 1.5°C warming and IPCC 2014 report RCP8.5 3.7°C mean warming scenario for 2100, ** IPCC Benign pathway is based on 1.5°C reached by 2052 as per higher bound scenario in the IPCC 2018 report and 1.7°C warming by 2100 as per IPCC 2014 report RCP2.6 scenario and ## Alarmist scenario is hypothetical

**2.0°C warming would be much worse than 1.5°C**

The IPCC’s 2018 report stressed that even 0.5°C more warming (2.0°C instead of 1.5°C) would lead to materially bad outcomes. In particular, the impact of extreme heat – 37% of the global population exposed to severe heat at least once every five years under the 2.0°C warming scenario rather than 14% under 1.5°C. Ice melt much worse – a sea-ice-free Arctic at least once in 10 years rather than once every 100 years and 38% worse permafrost thaw. Most impacts would be worse under 2.0°C vs. 1.5°C (source: IPCC).

**Chart 27: Half a degree of warming makes a big difference**

Source: IPCC, WRI
Atmospheric CO2 concentrations are already too high
Atmospheric CO2 concentration recently crossed the critical 400 parts per million (ppm) threshold. High levels of CO2 concentration create the “greenhouse” effect that keeps warming the planet. In the past 400,000 years, CO2 concentration had never crossed 300ppm until the 20th century, so the current era of >400ppm is uncharted territory. As annual emissions continue, the concentration is expected to keep increasing.

Chart 28: Atmospheric CO2 concentration long-term history shows current CO2 concentration significantly above 400,000-year highs

![Graph showing CO2 concentration over time](source: NOAA (National Oceanic and Atmospheric Administration))

Annual emissions still rising: China the biggest emitter, only Europe cutting CO2
Despite observed and forecast increases in temperature by agencies like the IPCC as well as dire warnings about the potentially catastrophic impacts of climate change, global CO2 emissions kept rising even in 2017-18 post the 2015 landmark Paris Climate Agreement. Global annual CO2 emissions rose from c.33GT (gigatons) in 2010 to c.37GT in 2018. As per 2017 data, China is the biggest CO2 emitter at c.11GT (>4x higher vs 1990 levels) followed by the US (c.5GT, flat), Europe (c.3.5GT, 20% lower) and India (c.2.5GT, up 4x). The rest of the world has also been a big contributor to higher CO2 emissions (12GT, up 2x).

Chart 29: Global carbon emissions continue to rise
CO2 emissions on the rise in 2017-18 after stabilising in 2014-16

![Graph showing CO2 emissions over time](source: Data from Global Carbon Project, Graphic from BofA Global Research)

Emissions history requires EU & US to do the heavy lifting on climate measures
China is the biggest emitter now, >2x more than Europe or the US, but China is not the biggest emitter cumulatively. If emissions from 1990 to 2017 are considered, Europe is the biggest emitter (c.510GT), followed by the US (c.400GT), China (200GT) and Russia.
(c.100GT). We believe it is important for Europe and the US to take the lead on climate mitigation, through technology and investments, given they account for almost 60% of the build-up of human-induced greenhouse gases in the atmosphere. In addition, the US and Europe consume a lot of the goods manufactured in EM, contributing to high emissions.

**Chart 31: Cumulative Global CO2 emissions by key regions / countries: Europe and the US biggest cumulative emitters in history**

CO2 the biggest greenhouse gas, followed by methane

CO2 contributes about three-quarters of annual greenhouse gases, followed by methane at c.17% and other gases (nitrous oxides, F gases) making up the c.9% balance. Different gases have different potency (heating potential) and length of impact (period of time the gases remain in the atmosphere and cause heating). GWP\(_{100}\), i.e. Global Warming Potential over a 100-year period, is a way of comparing gases relative to CO2 (CO2=1). Methane is about 28x more potent than CO2 on a GWP\(_{100}\) basis and even more so over shorter time periods, but it gets removed from the atmosphere faster than CO2.

**Chart 32: Cumulative CO2 emissions 1990-2017 (globally 1575 billion tons), Europe and US biggest cumulative emitters in history**

**Chart 33: Global greenhouse gas emissions by gas source, measured in tonnes of carbon dioxide equivalent (tCOe)**

**Chart 34: Global warming potential of greenhouse gases over 100-year timescale (GWP\(_{100}\))**

Source: data from "Our World in Data", BofA Global Research graphic, NB: Europe includes EU 28 (353 bn tons) and Other Europe (158 bn tons)
**Electricity, heat, transport and agriculture (+allied) contribute most GHGs**

There are different ways of looking at emissions by sector, for example, considering only CO2 or including other gases such as methane and nitrous oxides. Emissions can also be allocated to end-use sectors like industry and buildings rather than attributing them all to the power sector. 2010 GHG data from the EPA consider electricity & heat (25%), agriculture & allied activities (c.24%), industry (c.21%) and transport (c.14%) to be the biggest contributors. In terms of CO2, electricity & heat (c.42%) and transport (c24%) are the biggest emitters as per 2016 IEA data. If emissions from electricity and heat are allocated to the end-use sectors, then industry (c.37%), buildings (c.27%) and transport (c.25%) would be the biggest CO2 emitters. Overall, though, electricity & heat, transport and agriculture (and allied activities) are the sectors where emissions need to be reduced if overall levels are to be cut drastically, given these represent almost two-thirds of GHGs and a similar proportion of annual CO2 emissions.

**Chart 35: Global greenhouse gas emissions by sector 2010 (IPCC 2014)**

![Global greenhouse gas emissions by sector 2010](image)

Source: EPA, IPCC (2014 report), BofA Global Research graphic; * includes fossil fuel exploration, refining, processing & transportation

**Coal, oil and gas represent >90% of annual CO2 emissions**

In terms of fuel, coal and oil represent >70% of annual CO2 emissions globally. The share of gas is also rising, with gas used in heating, power generation and industry (e.g. fertilisers). Coal, gas and oil represent >90% of global CO2 emissions, so climate mitigation efforts ultimately have to target the use of these three fossil fuels.

**Chart 37: Global annual CO2 emissions by fuel type**

![Global annual CO2 emissions by fuel type](image)

Source: Data from “Our World in Data”, BofA Global Research graphic

**Chart 38: Global oil consumption has risen c.15% in 10 years (2008-18)**

![Global oil consumption has risen](image)

Source: BP Statistical Review 2019, BofA Global Research graphic
Ironically, oil & gas production has been rising, coal reducing only a little

Despite the recent climate focus, oil and gas production has been rising (+15% and c.28% vs. 2008, respectively). Even 2018 coal production was higher than in 2008 (peak. In 2012). Fossil fuel usage has been flat in developed markets (OECD countries) last decade but not down, while usage rose considerably in emerging markets (non-OECD countries). In our view, climate mitigation in DMs will not be enough given bigger EMs share now.

Developed markets emit much more per capita, so should make more effort

Developed markets (US, Europe) emit more per capita than emerging markets like India (China catching up with EU though). Emissions per capita in the US are 2.2 times higher than in China or 10 times higher than in India. But Americans are now emitting 18% less per head than in 2000, while Chinese are emitting 180% more than 20 years ago. Mature economies can focus on efficiency but in EM, growing demand for electricity, drinking water, or transport means growth is more carbon intensive. EM coal-dependent manufacturing is partly for goods consumed in DM, so limiting emissions in EM is key.

Developed markets seemingly have contributed to creating the problem by emitting nearly 900bn tons into the atmosphere (Chart 13) since 1900, but most of the growth in

Naturally, the politics of CO2 are very complicated...

Developed markets seemingly have contributed to creating the problem by emitting nearly 900bn tons into the atmosphere (Chart 13) since 1900, but most of the growth in
CO2 emissions now is driven by the emerging economies. Some developed markets are now facing steady declines in population while some emerging markets are still looking at decades of demographic growth ahead. These aspects make the politics of decarbonization very complicated. The brinkmanship between richer and poorer countries has strained climate talks in global (e.g. COP25) and regional settings (e.g. EU Green deal).

**Peak car, peak oil, peak meat, peak population will all help...**
Global oil demand is to peak by or before 2030 as share of electric vehicles in passenger car sales reaches ~40% on BofA estimates. EV sales are expected to take off in the early 2020s when EV costs converge with internal combustion engine vehicles and car manufacturers ramp production. But airlines and maritime transportation may continue to expand their carbon emissions, even though some airlines have recently announced plans to become carbon neutral. Given the carbon intensity of meat production (particularly cattle), a rotation to plant-based diets could also help curb global anthropocene carbon emission.

![Chart 43: We project global oil demand to peak by 2030 as the share of electric vehicle sales reaches 40% of total](chart43.png)

Source: BofA Global Research Estimates

![Chart 44: Given the carbon intensity of meat production, a rotation to plant-based diets in coming years could also help](chart44.png)

Source: Food and Agriculture Organization of the UN

**Decarbonising would require taxing global polluters via a CO2 price**
The Kyoto Protocol focuses mostly on reducing man-made emissions and places a heavier burden on developed countries. The parties to the Kyoto Protocol can utilize market based mechanisms, which include emissions trading, to meet their emissions targets. About 76% of GHG emissions come from CO2, the largest pollutant out there, with the second largest portion coming from methane. Emissions from the energy and agriculture sectors represent about 85% of anthropocene (human-made) carbon emissions. Even producing a research report takes energy (in the form of computing power) and agricultural commodities (in the form of food for the authors!).

**Carbon price could be key despite complicated history, regulations & politics**
In Europe, carbon taxes have not been nearly as effective at forcing a transition out of hydrocarbons as technology, competitive markets, and prices have been in the United States. Rather, we can attribute the biggest declines in European carbon emissions to the recessions of both 2008 and 2012. The good news is that US shale-driven collapse in global gas prices could encourage substitution out of thermal coal. Natural gas could be an important driver of global carbon emissions reduction, even if natural gas itself is ultimately phased out by renewable energy and energy storage.

**Natural gas could be the bridge fuel in transition to net zero**
Why is natural gas likely to play a key role in the energy transition towards a lower carbon economy? First, natural gas power generation can act both as baseload and
peakload. Second, with the massive ramp up of US liquid natural gas (LNG) exports, the
global gas oligopoly that kept prices so high is now broken and prices have declined.
Natural gas can provide flexibility at reasonable costs now. Even if natural gas is not
zero emission, gas plants can replace thermal coal plants and lower emissions. The
flexibility of gas helps when weather conditions limit renewable power.

**Chart 45: Massive ramp up of US LNG exports have weighed on global natural gas prices**

![Graph showing US LNG exports and Asia natural gas prices](source:Bloomberg, S&P Global)

**Current CO2 prices are still quite low (50% <$10/t)**

There are at least eight active CO2 credit trading systems worldwide, where the price of
carbon floats relatively freely. Launched in 2005, the EU Emissions Trading System (EU
ETS) was the first large emissions trading scheme in the world, and remains the biggest.
Other regions (like California or Ontario) also launched their own emissions trading
schemes. A free floating CO2 price system can be economically efficient way to reduce
carbon emissions. Alternatively, CO2 has also been taxed on a fixed basis in countries
like Norway or Argentina. Although some existing taxes exceed $100/t CO2e, about half
of the emissions covered in programs are below $10/t CO2e.

**Chart 47: There are various trading systems active in the world, where
the price of carbon floats relatively freely**

![Bar chart showing carbon prices in implemented carbon trading programs](source:World Bank, Note: Pricing initiatives may not cover the entirety of each country and are not necessarily comparable between countries due to differences in sectors covered and exemptions allowed)

**Chart 48: Alternatively, CO2 is taxed on a fixed basis across many regions**

![Graph showing carbon taxes in implemented carbon tax programs](source:World Bank, Note: Pricing initiatives may not cover the entirety of each country and are not necessarily comparable between countries due to differences in sectors covered and exemptions allowed)

**But carbon price systems can be made to work, e.g. Europe and California**

While efficient from an economic theory standpoint, the EU ETS experienced numerous
setbacks in the past 15 years including over-reporting at start, over-allocation of
certificates, recession-led drops and lack of adjustment mechanisms. More recently, the
EU ETS has been largely fixed with a more robust self-adjusting system and carbon prices have recovered to ~€25/t from <€10/t. In California, the power sector carried the emissions reduction load but easy coal reductions have already happened.

**Chart 49: In Europe, the freely traded price of CO2 has suffered numerous setbacks in the past 15 years**

Source: Bloomberg, BofA Global Research

**Chart 50: In California, the escalating floor will probably force a rising cost of carbon in the golden state**

Source: CARB, MLCI, BofA Global Research estimates

**Scenarios for decarbonization to 2050 and carbon pricing**

There are many variables that could influence carbon emissions pathways and carbon pricing including (1) relationship between projected economic growth and energy consumption, (2) energy efficiency assumptions, (3) shifts in technology and (4) policy.

**Considerations for a central scenario on rising carbon prices**

Potential topics to keep in mind when trying to establish a central scenario for carbon prices which would be higher than current levels (1) gradually tightening emission policies worldwide, (2) relatively low natural gas prices, (3) rising carbon prices, (4) peaking of global energy demand by 2040, (5) DM exiting coal but EM coal still continuing and (6) growth in renewable energy + energy storage. While such a central CO2 price scenario could mean higher carbon prices than seen today, such price levels may not yet be enough to substantially reduce climate-related risks.

**Considerations for an aggressive climate action scenario on high carbon prices**

In an aggressive climate action scenario, the topics to consider for a much higher carbon price would be (1) global coordinated policies, (2) fast technological progress in cleantech, (3) early peak in global fossil demand, (4) fast adoption of EVs and (5) economic incentives needed for technology like carbon capture and storage (CCS).

**Considerations for a business-as-usual scenario, with CO2 at current lows**

Last but not least, in a business-as-usual (BAU) scenario, a combination of limited policy action, low carbon credit prices and cheap hydrocarbons, together with limited technological progress, results in global hydrocarbon demand continuing to grow into 2050 and delay in peak oil demand towards 2040. Such a BAU scenario still would require substantial progress in technology and adoption in areas such as EVs and renewables but would not mitigate fossil demand materially to solve the climate crisis.
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